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CONTENTS

Volume I, Number 1

Volume II, Number 1

Supplement to Volume II, Number 1

Volume II, Number 2

AUTHOR INDEX

SUBJECT INDEX

SUPPLEMENT TO
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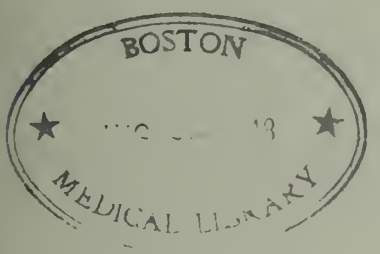
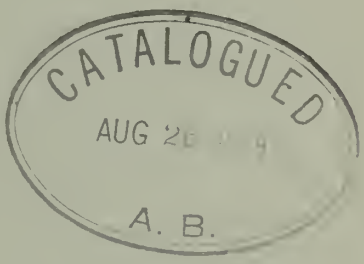
VOLUME 2 AUGUST, 1943 NUMBER 1





A MALARIA SURVEY OF TRINIDAD AND TOBAGO BRITISH WEST INDIES

BY

W. G. DOWNS, H. P. S. GILLETTE, and R. C. SHANNON

A MALARIA SURVEY OF TRINIDAD AND TOBAGO BRITISH WEST INDIES[1]

[1]The studies and observations on which this paper is based were conducted with the support and under the auspices of the Medical Services of the Crown Colony of Trinidad and Tobago, British West Indies and the International Health Division of The Rockefeller Foundation.

by

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MALARIA LABORATORY, TRINIDAD,
BRITISH WEST INDIES

MALARIA SURVEY OF TRINIDAD

A MALARIA SURVEY OF TRINIDAD AND TOBAGO

BRITISH WEST INDIES

Malaria has long been regarded as the foremost public health problem of Trinidad and Tobago. Notable progress in control measures has been achieved in the past in various parts of the Colony but the disease still remains a formidable enemy of the rural and coastal areas.

The Crown Colony of Trinidad and Tobago consists of these two islands off the coast of Venezuela, just north of the mouth of the Orinoco River. Trinidad lies between 10°3′ and 10°44′ N. latitude and 60°55′ and 61°44′ W. longitude. The island is roughly rectangular in shape, with large promontories on the northwest and southwest. It is seven miles from the promontory at the southwest corner of the island to the Venezuelan coast. The area of the island is 1,863 square miles. Its greatest length is 50 miles from north to south and greatest breadth 32 miles from east to west. Port of Spain, population about 90,000, is the largest city of the colony. Tobago, 25 miles long by three to seven miles wide, lies about 30 miles northeast of Trinidad.

Both Trinidad and Tobago were discovered by Columbus in 1498. Trinidad was ceded to Great Britain by Spain in 1802. Tobago, after several changes, was ceded to Great Britain by France in 1814.

The Colony is officially termed a Crown Colony and is administered by a Governor assisted by an executive and a legislative council. The United States government established military bases in Trinidad in 1941 under the terms of the Lend-Lease Bill.

The Health Service of the Colony has at its head the Director of Medical Services and consists of District Medical Officers for the relief of indigents and Medical Officers of Health for Public Health Services. The Director of Medical Services is also Chairman of the Central Board of Health which supervises and coordinates the work of the local health bodies. These local health bodies or local health authorities are purely nominated bodies set up in various parts of the Colony, except in Port of Spain and San Fernando where the elected city councils constitute also the local health authority.

TOPOGRAPHY AND GEOLOGY

R. C. Marshall (1) has summarized observations on topography, geology, and meteorology in a recent publication, and much of the data herein included was obtained from this source.

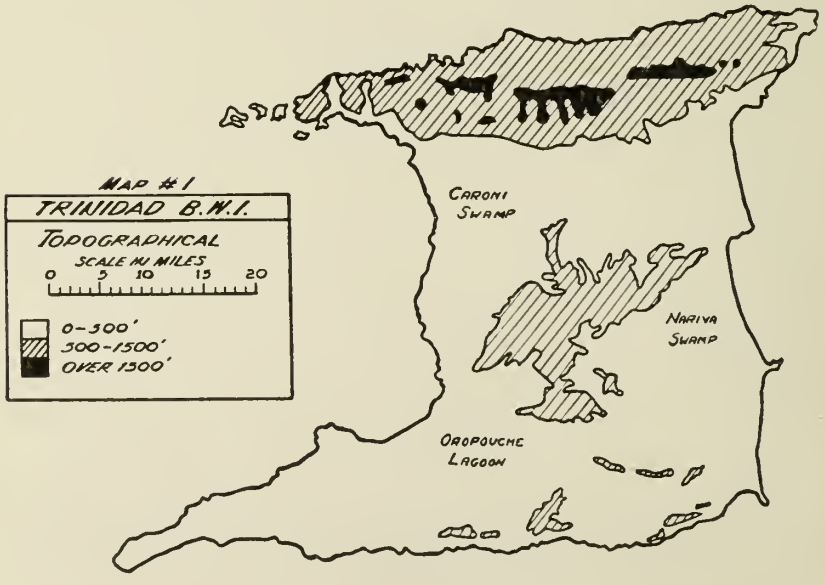
The island of Trinidad can be divided into five belts. Three ranges of mountains and hills run more or less from east to west, and there are two intervening lowlands:

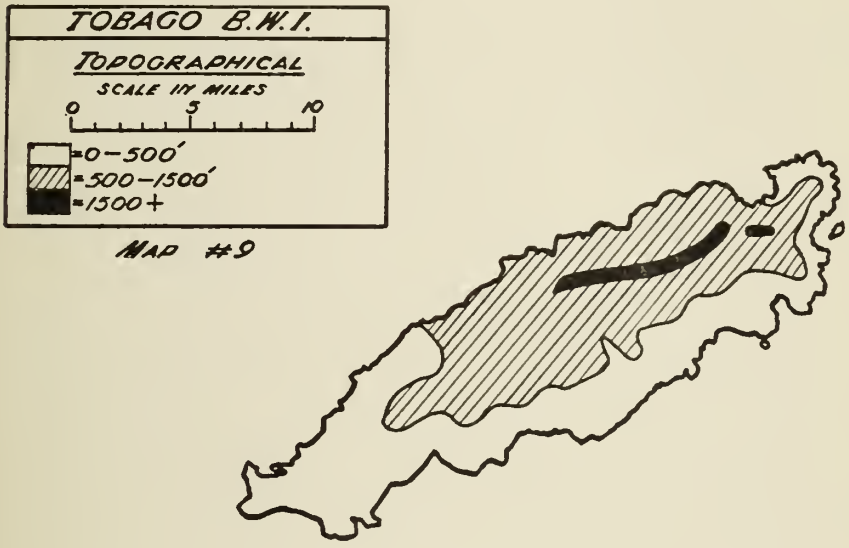
(1) The first belt or Northern Range consists of a range of mountains 55 miles in length from east to west and seven to ten miles in breadth, from north to south. Two peaks rise above 3,000 feet, and several above 2,000 feet. The range is clothed with dense forest most of which is evergreen.

(2) The second belt is an alluvial plain lying south of the mountain range. The plain, most of which has an elevation of less than 100 feet, includes about one quarter of the Island. The Caroni River which drains most of the plain flows to the west, emptying into the Gulf of Paria. The Caroni Swamp is located at its mouth. The Oropouche River (of the North) drains to the east into the Atlantic Ocean. The width of the plain is generally about ten miles, narrowing in places to five miles, and opening out at its western end to about 20 miles, at the Caroni Swamp.

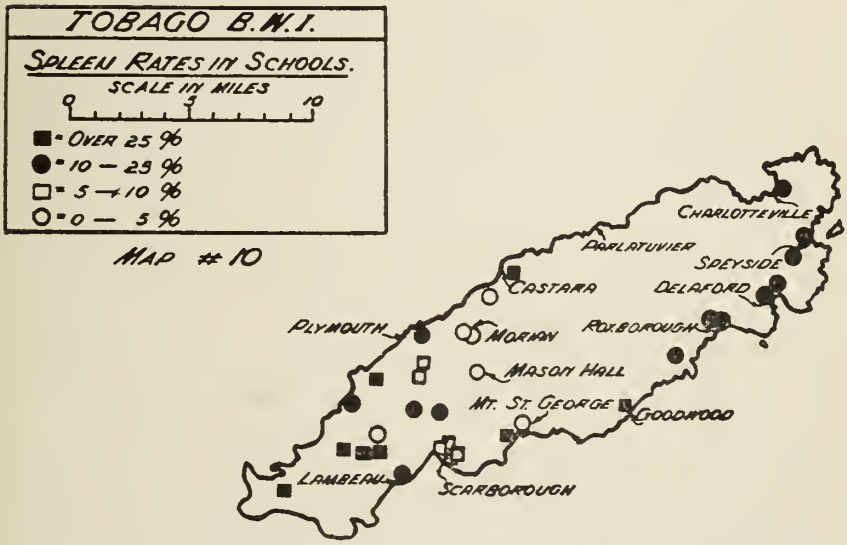
(3) The third belt is the central range of hills, stretching across the island in a northeasterly-southwesterly direction. The highest elevation of the range is 1,000 feet.

(4) The fourth belt is a plain lying between the central range and the southern range of hills. The Oropouche





MAP #9



MAP #10

River (of the South) drains to the west, emptying into the Gulf of Paria. The Nariva and Ortoire Rivers drain to the east, emptying into the Atlantic Ocean. The Nariva Swamp, the largest swamp on the island, lies in the eastern portion of this belt.

(5) The fifth belt is a low range of hills running east to

west near the south coast. The maximum elevation is 997 feet. The island of Tobago has a low lying portion in the southwest and a mountainous portion in the northeast, with hills rising to 1,000 feet. Map No. 1 illustrates the main topographic features for Trinidad. Map No. 9 illustrates the main topographic features for Tobago.

Trinidad conforms generally with the geological structure of the adjacent Venezuelan coast and consists almost entirely of sedimentary rocks. There is a small patch of igneous rock in the northeastern part of the Island. A considerable area of the island is covered by recent alluvial deposits varying from mud flats with mangrove swamps in tidal areas through semi-swamp conditions to higher lands, usually used for sugar cane production. Petroleum has been found in quantity in southern Trinidad. The well known Pitch Lake, comprising about 100 acres of asphalt, is on the southwestern promontory.

Tobago is formed chiefly of metamorphic rocks, some of sedimentary and some of igneous origin.

METEROLOGY AND HYDROGRAPHY

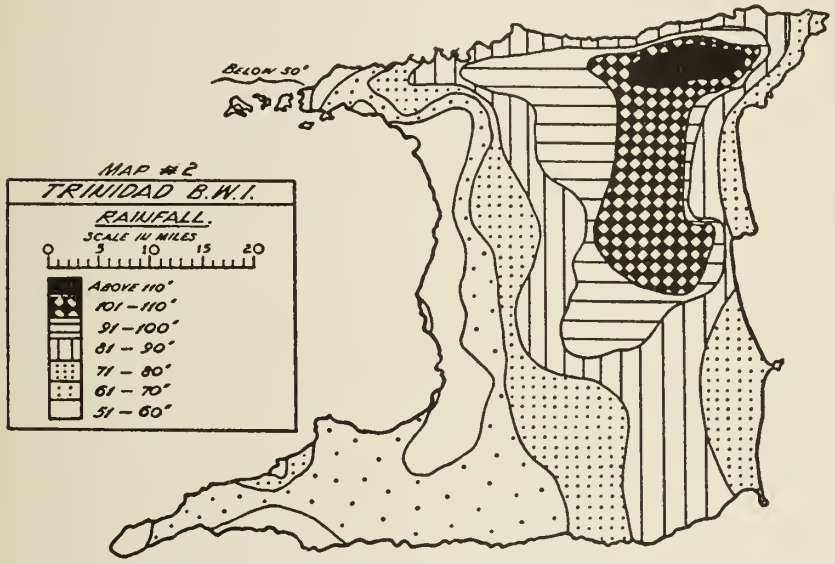
(Data for this discussion has been obtained largely from Marshall (1), Bain (2), and from records in the Department of Agriculture).

The Islands have a tropical climate and except for seasonal changes in rainfall, remarkably little climatic diversity. The following table illustrates this.

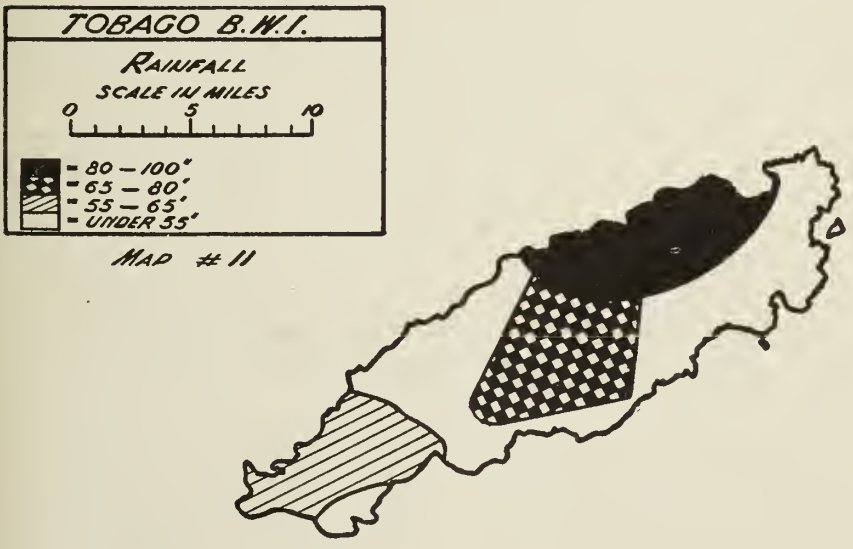
TABLE I.

Temperature, Humidity and Rainfall
St. Clair Experiment Station, Port of Spain

Month	Temperature 1916 - 1932				Humidity 1916 - 1932		Rainfall (70 year period).
	Max. °F.	Min. °F.	Range. °F.	Mean. °F.	7 a.m. %	3 p.m. %	
January	86.4	68.2	18.2	77.3	92.9	67.5	2.70
February	86.5	6.76	18.9	77.1	92.8	63.0	1.48
March	87.2	6.79	19.3	77.6	93.4	62.2	1.80
April	88.8	69.3	19.5	79.1	92.3	59.9	1.86
May	89.8	70.5	19.3	80.2	91.3	59.5	3.46
June	87.4	71.0	16.4	79.2	92.4	66.3	7.65
July	87.4	71.0	16.4	79.2	98.2	72.9	8.74
August	87.2	71.3	15.9	79.3	94.5	72.9	9.52
September	87.8	71.8	16.0	79.8	94.1	73.5	7.29
October	88.7	71.5	17.2	80.1	94.3	72.2	6.66
November	88.2	71.0	17.2	79.6	94.2	74.2	7.10
December	87.3	69.7	17.6	78.5	93.4	72.8	4.78
							63.03



OBSERVATIONS OVER PERIOD 1910–1932.



For this station, the mean temperature variation is 3.1°F. The mean temperature curve shows two minima and two maxima, occurring in February and July and May and October respectively.

During the dry season, from midnight to dawn the humidity approaches saturation point. Shortly after sunrise it then decreases rapidly and remains low until evening. During the rainy season, humidity approaches saturation from 8 p. m. until after dawn. It drops rapidly after sunrise, but rises at some time during the day, depending on the hour when rain falls.

The distribution of rainfall over Trinidad can be seen from Map No. 2. Rainfall for Tobago is shown on Map No. 11. According to locality, average yearly figures may range from less than 50 inches to over 110 inches. The year may be divided into a wet season and a dry season. The dry season extends from January through May and the wet season from early May through December. There is a short period of dry weather during September and October, known as "Indian Summer." Marshall (1) has a series of charts showing the monthly distribution of rainfall both for Trinidad and Tobago. Records over a period of years show that there may be considerable yearly and monthly variations in rainfall, depending on whether the season is a "wet year" or a "dry year."

The heaviest rainfall occurs on the northeastern, eastern and north central portions of the island. The moisture-laden northeast trade winds, sweeping in from the ocean, strike this part of the island, and the Northern and Central mountain ranges first. Westward along the Northern Range the zone of heavy rainfall continues, but, south of this range, the western half of the island receives considerably less rain than the eastern half.

The direction of the wind is, almost throughout the year, from the East, the well known Trade Winds. Velocities rarely reach pronounced intensities.

The prevailing local opinion is that wind affords some degree of protection to localities situated eastward of breeding areas. This, however, does not necessarily hold true as, almost invariably, the wind or breeze dies down at sunset, when the main flight of Anopheles begins.

The largest rivers are the Caroni River, draining the western portion of the central plain, the Oropouche River (north) draining the eastern portion, and the Oropouche (south), Couva, Erin, Nariva and Ortoire rivers in the south and east. Many of the smaller streams gain access to the ocean independently, and their mouths are often blocked by sand bars. The sand-blocked streams are important in connection with malaria. Most of the smaller

streams carry little or no water during the dry season. During heavy rains they may become roaring torrents. There are very few natural ponds, and no lakes exist. The Quare Dam, an artificially impounded reservoir supplying a large part of the island with its drinking water, is located in the mountains in the northeastern end of the Northern Range. There are numerous small artificial ponds in the agricultural regions, for watering stock and general household purposes. Occasionally these are maintained in good condition but very often they are abandoned and overgrown with vegetation.

There are several large swamps on the island. The Caroni Swamp and the Nariva Swamp are the largest. The Caroni Swamp (12,800 acres) is situated in the northwest corner of the island. The section of it known as the Laventille Swamp is contiguous to Port of Spain, and populous communities along the main road going east from Port of Spain border it. The Nariva Swamp (16,000 acres) lies in the middle of the east coast. Few people live in or near this region. The Oropouche Lagoon, (3,800 acres) occupies the southwest angle of the west coast and the Icacos Lagoon (700 acres) is at the very southwest "toe" of the island. Apart from local precipitation over their surfaces, most of these swampy areas probably obtain their water from seepage and from blind terminations of streams flowing into them. Attempts have been made and are still being made to reclaim some of these areas.

The swamps are largely overgrown with mangrove. Williams (3) lists six species as occurring on the island. Open, boggy areas of the marshes are frequently overgrown with Montrichardia and Achrosticum.

In several of the swampy sections of the island, the East Indian peasants cultivate rice, using primitive cultivation and irrigation methods.

It is necessary to call special attention to another type of water collection because of its peculiar relation to the malaria problem. It consists of innumerable tiny pools of water held in the leaf axils of certain plants, members of the family Bromeliaceae. A large number of species occur in Trinidad where they are locally called "wild pines" and "zanana." The well known pineapple is a member of this group of plants. Although all species of the group resemble the pineapple in general structure and arrangement of leaves, most are arboreal in habit and are commonly termed epiphytes. Some of these epiphytes hold as much as two or even three liters of water and in areas of high rainfall may hold water throughout the year. In a tree which holds 40 or 50 of these plants

they constitute what might be regarded in the aggregate as an overhead pond of water. The relationship of these plants to the malaria problem on the island will be discussed later.

POPULATION STATISTICS

The population of Trinidad and Tobago at the time of the 1931 census (4) was 387,425 and 24,358 respectively, a total of 411,783. It is difficult to estimate the population of the islands at the present time, due to a great influx of laborers from neighboring islands, military personnel and contractors and construction men from the United States. But the population December 31, 1941, has been estimated by the Registrar General at 506,316.

The Colony is divided into three towns, eight counties and the ward of Tobago. Data for these political divisions are given in the following table.

TABLE II.

Area, Population and Density of Populations of the Major Political Divisions of Trinidad and Tobago, Census of 1931.

Town or County	Area in Square Miles	Population	Number of People per Square Mile
Port of Spain (town)	2.80	70,334	
San Fernando (town)	1.05	14,353	
Arima (town)	.91	5,089	
St. George (county—excluding Port of Spain and Arima)	355.06	85,904	242
St. David (county)	78.95	5,664	72
St. Andrew (county)	282.74	23,337	83
Nariva (county)	206.30	10,609	52
Mayaro (county)	145.69	4,037	28
Caroni (county)	213.99	51,193	239
Victoria (county—excluding San Fernando)	313.53	60,086	192
St. Patrick (county)	260.80	46,531	178
Totals: Trinidad	1,863.82	377,337	203
Tobago (island ward)	116.24	24,358	210
Totals: Trinidad and Tobago	1,980.06	401,895	203

In the 1931 census there were recorded 92,976 children between 5 years and 15 years of age; 47,066 males and 45,910 females. At this time there were 290 schools on the islands, with 66,111 children enrolled and with an average attendance of 43,109. At the time our investigations were conducted (1941) there were 286 schools with 105,796 children enrolled and an average attendance of 50,970.

In September 1942, the Government of Trinidad and Tobago introduced national registration for wartime purposes. As a result new population figures, not as accurate as those obtained in census, are now available.

TABLE III.

Population Returns (National Registration, September 26, 1942)

PORT OF SPAIN		
(a) North Western	11,976	
(b) South Western	14,155	
(c) Central	7,234	
(d) North Eastern	18,946	
(e) South Eastern	22,954	
(f) St. James	8,112	83,377
SAN FERNANDO		28,652
ARIMA AND DISTRICTS		15,917
COUNTY ST. GEORGE (Excluding Port of Spain and Arima)		
(a) Diego Martin	10,721	
(b) St. Ann's	23,410	
(c) Tacarigua	31,252	
(d) Caura	1,862	
(e) Arouca	3,421	
(f) Blanchisseuse	1,380	
(g) San Rafael	3,967	76,013
COUNTY ST. DAVID		4,739
COUNTY ST. ANDREW		
(a) Valencia	745	
(b) Matura	1,360	
(c) Sangre Grande	12,158	
(d) Tamana	1,380	
(e) Turure	1,170	16,813
COUNTY CARONI		
(a) Cunupia	7,977	
(b) Chaguanas	12,023	
(c) Couva	21,394	
(d) Montserrat	8,605	49,999
COUNTY VICTORIA		
(a) Point-a-Pierre	18,335	
(b) Naparima	26,863	
(c) Savana Grande	19,829	
(d) Ortoire	5,953	
(e) Moruga	5,158	76,138
COUNTY ST. PATRICK		
(a) Erin	4,931	
(b) Cedros	5,006	
(c) La Brea	18,517	
(d) Siparia	34,011	62,465
COUNTY NARIVA		12,542
COUNTY MAYARO		4,380
WARD OF TOBAGO		
(a) Northern	6,149	
(b) Scarborough	2,806	
(c) Middle	2,584	
(d) Windward	5,647	
(e) Leeward	4,066	
(f) Charlotteville	2,250	
(g) Castara	1,100	24,602
Returns sent in by business houses, offices and institutions		46,764
TOTAL		502,401

Many persons failed to register up to September 26th, the last day of registration. They are still doing so, thereby adding to the aggregate of registrants.

The registered population does not include members of the local armed forces, nor members of British, American and Canadian army, navy and air units stationed in Trinidad.

The census report does not give an analysis of the population of Trinidad by race. The present population has been derived from many sources. The predominant racial types are negroes and East Indians. The Carib Indians, the original inhabitants of the islands, have almost completely disappeared.

Negroes and those of Negro descent form nearly two-thirds of the population of the islands. Their date of arrival coincides with the first attempts at colonization in the early sixteenth century. The slave trade was abolished in 1807 and slavery was finally abolished in 1838.

East Indian immigration began in the year 1845. For many years, East Indians were brought into Trinidad from India, as indentured laborers, to work on the sugar cane and cocoa plantations. After a certain period of service they were given the choice of a plot of land in Trinidad, or a return passage to India. Thousands elected to remain in Trinidad and the 1931 census indicates 138,667 East Indians or descendants of East Indians in Trinidad and Tobago. Immigration of East Indians ceased in 1916. More than half of the East Indians are Hindus, with smaller proportions of Mohammedans and Christians.

The first Chinese arrived in Trinidad in 1806 from Macao. Later Chinese immigrants were brought to the Colony under Government license in 1853 and continued to arrive intermittently until 1866, when immigration ceased. The Chinese colony in Trinidad and Tobago in 1931 numbered 5,239.

The number of Europeans residing permanently or for one year or more probably does not exceed 5,000 (these figures are too low if the recent large influx of American civilian and military personnel is included). During very early days, a number of French families settled in the islands, and have become an integral part of its population. Smaller numbers of Portuguese settlers came to Trinidad early in the nineteenth century. There are also small numbers of Syrians and other nationalities.

The senior officials and business men of the Colony are largely natives of the United Kingdom. Small numbers of other Europeans, Americans and Canadians are here chiefly engaged in business in Port of Spain and in oil production in South

Trinidad.

There has been in the past a considerable admixture of races. Mulattos (European-African) constitute most of the group, but also Afro-Chinese, Afro-East Indian and other types are not uncommon.

ECONOMIC DEVELOPMENT

The population of the islands is largely engaged in agricultural pursuits, as the following table indicates.

TABLE IV.

Numbers Gainfully Employed, Trinidad and Tobago, 1931

Professional	5,131
Agricultural	78,606
Commercial	13,774
Industrial (largely oil fields)	31,774
Domestic	24,049
Not gainfully employed	13,045

The Colony is estimated to contain 1,267,200 acres, of which about 556,000 belong to the Crown and about 300,000 acres are under cultivation.

Until the end of the first World War the prosperity of the Colony depended entirely on agriculture. Sugar cultivation has been and still is the chief agricultural activity and until recent years cocoa was a close second. Latterly, however, the cocoa industry has suffered much — largely as the result of three factors:— (1) reduction in cocoa prices, (2) increased cost of labor and (3) damage caused by "Witch Broom," a fungus disease of cocoa.

An analysis of the acreage devoted to various crops and the value of agricultural exports is included in the following table.

TABLE V.

Acreage and Export Value of Certain Crops of Trinidad and Tobago for 1938

Crop	Acreage	Export Value Pounds Sterling
Cocoa	180,000	493,601
Sugar	82,000	1,074,316
Coconut	40,000	49,039
Rice	10,000	
Coffee	7,000	8,438
Vegetables	7,000	
Citrus	7,000	123,758
Tonka Beans	5,300	17,463
Corn	3,000	
Bananas	2,000	9,174
Miscellaneous	5,000	

Sugar is grown chiefly in the wide central plains of the island and in South Trinidad, near San Fernando, Princes Town

and Couva. The sugar estates are usually large plantations but in 1938 there were 17,000 small cane farmers, mostly East Indians, who supplied 44% of the total cane ground.

Cocoa plantations are scattered over the islands but the areas of heaviest cocoa cultivation are in Tobago and in the Sangre Grande-Cumuto-Tamana sections of central Trinidad. There are also numerous plantations in the Northern Range valleys stretching westward, in the Moruga district in South Trinidad and in the Penal-Siparia district in southwestern Trinidad. The cocoa estates are not as large as the sugar plantations and there are many small peasant proprietors. Mainly owing to factors mentioned before, cocoa has fallen on evil days. In 1929, over 61 million pounds of cocoa valued at nearly one and a half million pounds sterling were exported. Ten years later exports had dropped to 42½ million pounds valued at half a million pounds sterling.

Citrus fruit cultivation has been a profitable venture in recent years in certain areas.

Coconuts are chiefly a coastal cultivation and large plantations are found in southern Tobago, and at Cedros, Icacos, Toco and the Cocal in Trinidad. Edible oil and soap are manufactured locally from copra.

Rice is grown in the lowlying areas around the Caroni swamp, and in the Oropouche Lagoon region in south Trinidad. East Indian peasant proprietors grow most of the rice, and most of the crop is consumed locally.

Oil mining is a major industry in Trinidad and has brought much wealth to the colony. No oil is found in Tobago. The development of the oilfields has taken place largely in the last quarter of a century.

The larger towns and villages have a more or less fixed population. There is much migration from all parts of Trinidad to the oil fields in the south. Movement among agricultural laborers does not occur as frequently as in the past and the number of people moving from district to district is not great. During the past two years (1940-42), however, there has occurred an extraordinary but transient movement of population, with the esablishment of the bases for the United States Army and Navy, under the terms of the lease bill.

VITAL STATISTICS

Records on morbidity and mortality for several diseases are available for many years past but for present purposes the value and usefulness of these records is lessened by the system of report-

ing disease largely on the basis of clinical evidence only. A summary of these records for the past fifteen years is presented here.

TABLE VI.

Mortality Rates of Trinidad and Tobago, 1927-1941
Death Rate per 1,000

Year	All Causes	Malaria	Pulmonary Tuberculosis	Enteric Fever
1927		2.09		
1928	19.4	1.61	1.07	.65
1929	19.8	2.18	1.04	.55
1930	18.9	1.58	.94	.83
1931	19.9	1.77	.93	.89
1932	17.1	1.39	.85	.59
1933	19.6	1.65	.97	.56
1934	18.8	1.42	.95	2.16
1935	17.5	1.19	1.00	2.30
1936	16.3	1.05	.93	1.30
1937	17.4	1.11	.89	1.45
1938	15.82	1.07	.80	.25
1939	15.97	.97	.99	.23
1940	15.65	.90	.94	.23
1941	15.95	.98	.97	.26

Despite small fluctuations in the death rates from year to year, there seems to be a definite tendency to a declining mortality, both from all causes and from malaria.

Malaria is not a notifiable disease, and the morbidity statistics are even more liable to error than the mortality statistics. Table VII gives the number of cases reported by health officers from all parts of the island. The average rainfall for the year is included in this table. Table VIII gives the results of examinations of blood smears (mostly thin smears) in the Government Bacteriological Laboratory in Port of Spain. Most of these smears were taken, either from patients who came to the Colonial Hospital, or from patients of the private practitioners in Port of Spain and close environs.

TABLE VII.

Number of Clinically Diagnosed Cases of Malaria in Trinidad and Tobago and Average Annual Rainfall in Trinidad.

Year	Number of Cases of Malaria	Average Annual Rainfall in Inches
1931	17,287	56.21
1932	16,325	83.96
1933	21,213	78.03
1934	19,549	55.35
1935	23,978	60.65
1936	18,902	63.05
1937	18,518	58.00
1938	19,015	90.14
1939	19,599	56.16
1940	20,691	51.93

TABLE VIII.

Slides Examined for Malarial Parasites, Government Bacteriological Laboratory, Port of Spain, Trinidad

Year	Total	Negative	Positive	*P. vivax*	*P. malariae*	*P. falciparum*
1932	524	429	95	10	0	85
1933	598	498	100	18	4	78
1934	722	622	100	11	2	87
1935	916	796	120	16	2	104
1936	1,127	971	156	19	5	132
1937	1,570	1,246	324	54	3	267
1938	1,899	1,549	350	43	0	307
1939	1,605	1,396	209	47	0	162
1940	1,976	1,623	353	48	0	305
1941	1,741	1,420	321	79	0	242
	12,678	10,550	2,128	345	14	1,769

No statistics are available on the number of cases of malaria seen by private practitioners.

There are not sufficient data on hand to draw up an accurate chart revealing the seasonal incidence of malaria. However, available figures and the statements of practicing physicians indicate that more cases of malaria are seen in the rainy season which occurs in the latter half of the year than in the dry early half of the year. As shown in Table VII, however, it does not appear possible to correlate the numbers of cases per annum with the annual yearly rainfall.

PAST HISTORY OF MALARIA AND MALARIA INVESTIGATIONS

Malaria has been, and continues to be, one of the most prevalent diseases in Trinidad and Tobago. Less than fifty years ago, both Port of Spain and San Fernando, the two largest towns, were malarious, and many cases are said to have arisen in people in the center of the towns. With the growth of these towns many of the anopheline breeding areas were eliminated and very few cases are now contracted within the town limits. However, many of the rural areas of the island are still very malarious, as shown by the analysis of the data from this survey.

Tobago has long been known as a malarious island and it is claimed that in years past blackwater fever was unusually prevalent there, although rare on the island of Trinidad (5). At the present time, blackwater fever is rare both in Trinidad and Tobago.

A number of reports on malaria and anophelines of Trinidad have been published in the past (6, 7, 8, 9, 10, 11, 12, 13, 14), but it is difficult to trace through these writings the origins of the concept of specific malaria vectors among the local anophelines.

Early reports comment on the abundance of *A. aquasalis*

Curry (usually reported as *A. tarsimaculatus* (Goeldi) but also as *A. albimanus* Wied., and *A. albipes* Theob.), in the lowlands of Trinidad (5) but it is not until 1913 that Urich (6) states that this species is a vector. He says: "*A. tarsimaculatus* is the commonest [anopheline] occurring all over Trinidad wherever favorable conditions exist, viz. man and suitable breeding places near his house. It is the principal carrier of the malaria parasite if not the only one." Lassalle (8) in his 1920 Report says that *A. albipes* (= *aquasalis*) and *argyrotarsis* (= *albitarsis*) convey malaria in the Colony. De Verteuil in 1925 (9) states: "The studies of Darling and others in Panama leave little doubt that *tarsimaculatus* and *albimanus* (which form about 80 to 90 per cent of the total number of anophelines in the populated parts of the island) are here the usual carriers of benign tertain and quartan fevers. The following observations, made over a number of years, have led me to believe that the usual carriers of malignant tertian are *argyrotarsis* (*albitarsis*) and *maculipes* (*neomaculipalpus*), or both. Together they constitute about 5 to 10 per cent of all *Anopheles* and have been found in most parts of the island." However, in 1931, De Verteuil (11) states that there can be little doubt that *A. tarsimaculatus* is in all probability the most important malaria vector in Trinidad. He mentions the dissection of 80 house caught females, finding oocysts on the stomachs of four. This is the first record of dissections of Trinidad anophelines. In these earlier reports, *A. aquasalis* Curry is not differentiated from *A. oswaldoi* Peryassu, both being grouped broadly under the name *A. tarimaculatus* Goeldi. De Verteuil in his Report for 1932 distinguishes between *aquasalis* and *oswaldoi* and indicates that the former is the important malaria carrier in Trinidad. He emphasizes the importance of this observation for the proper orientation of future control work.

The history of the position of *A. bellator* as a vector of malaria in Trinidad is even more difficult to trace. Boyce (5) in 1909 observes: "Mr. Urich is describing a bromelia Anopheline, which he thinks may be a source of malaria upon the cocoa and other plantations . . . . [namely] *A. bellator*, D. & K. . . . . a forest inhabiting species living only in Bromeliae. It is found in hills where there is no ground water. It is also found on cocoa estates, where Bromeliae are allowed to thrive in abundance on shade trees, common in forests all over the island and on many cocoa estates. My [Urich's] attention has often been called to the fact by country people that fever is prevalent in recently felled land: I put it down to this species and not to *A. tarsimaculata*." However, in Urich's

1913 list of mosquitoes (6), this author mentions *A. bellator* but makes no statement about its position as a vector, in the same report in which he mentions the importance of *A. tarsimaculatus*. Lassalle (8) in 1920 remarks that *A. bellator* has not been recognized as a malaria carrier. De Verteuil (14) states in 1934 that there is no evidence that *A. bellator* is a vector of malaria. However, in 1937 (15) after further investigations, he states that the high malaria incidence of certain of the inland, hilly, cocoa-growing districts of Trinidad is due to *A. bellator*. He gives an interesting discussion of their breeding and feeding habits and remarks that the methods of cocoa cultivation, with the planting of immortelle trees to shade the cocoa, results in very heavy growths of bromeliads on these trees and provides extensive breeding sites for *A. bellator*. He concludes that this is but one more example of man-made malaria. Rozeboom and Laird (17) in 1941 carried out an extensive investigation of the problem of malaria in inland Trinidad and confirmed De Verteuil's impressions that *A. bellator* was an important vector of malaria on the island. They dissected 725 mosquitoes and found three infected, two with oocysts, one with salivary gland infections. They also succeeded in infecting the species experimentally. This is the first time that a member of the subgenus *Kerteszia* has ever been implicated definitely as a vector of malaria, although various species of Kerteszia in other countries have likewise been suspected (18, 19, 20 & 21).

De Verteuil (9) in 1925 first brings up the question of malaria transmission in Trinidad by *A. albitarsis* (referred to as *A. argyrotarsis*) and *A. neomaculipalpus* (referred to as *A. maculipes*). He mentions these species frequently in later publications but considers that, even though they may be vectors, they are decidedly secondary in importance to *A. aquasalis*.

PRESENT SURVEY

Examination of school children in all the schools of Trinidad and Tobago was carried out. Dr. H. P. S. Gillette devoted himself exclusively to this task from September 1941 to April 1942, so all the examinations were made by the same examiner using the same technique. From one half to two thirds of all the children in attendance in each school between the ages of 5 to 15 inclusive were examined for splenomegaly, in the recumbent position with knees flexed. Results were recorded according to the classification of Boyd. Blood smears, thick and thin, were made on all children with enlarged spleens and on one quarter

of the children without enlarged spleens. Smears were stained by Giemsa stain. Thick smears were examined routinely for five minutes under oil immersion before a negative result was accepted. Infections were classified as to species of parasite present but no attempt was made to estimate the density of parasites or to record the presence or absence of gametocytes. The races in the population are classified as Negro — that is, of pure African descent — "mixed" — that is, mixtures of African and white — East Indian and "others" which includes Europeans, Chinese and mixtures involving East Indians, Chinese and Europeans with other races.

SPLEEN AND PARASITE RATES IN SCHOOL CHILDREN

Two hundred and eighty-six schools were visited between September 1941 and April 1942, and 26,349 children were examined for splenomegaly. This figure represents approximately one quarter

TABLE IX.

Racial Distribution of School Children in Trinidad and Tobago

County	Negro	Mixed	East Indian	Other	Total
St. David	425	89	6	26	546
St. Andrew	531	219	514	84	1,348
St. George	1,780	945	1,488	382	4,595
Port of Spain	2,548	1,008	435	383	2,741
Caroni	619	191	1,777	154	2,741
Mayaro	143	33	12	12	200
Nariva	153	78	392	27	650
St. Patrick	953	222	1,399	142	2,716
Victoria	2,332	574	3,455	383	6,744
Tobago	2,110	257	18	23	2,408
Total	11,594	3,616	9,498	1,616	26,234

TABLE X.

Data from Spleen Examinations of School Children in Trinidad and Tobago

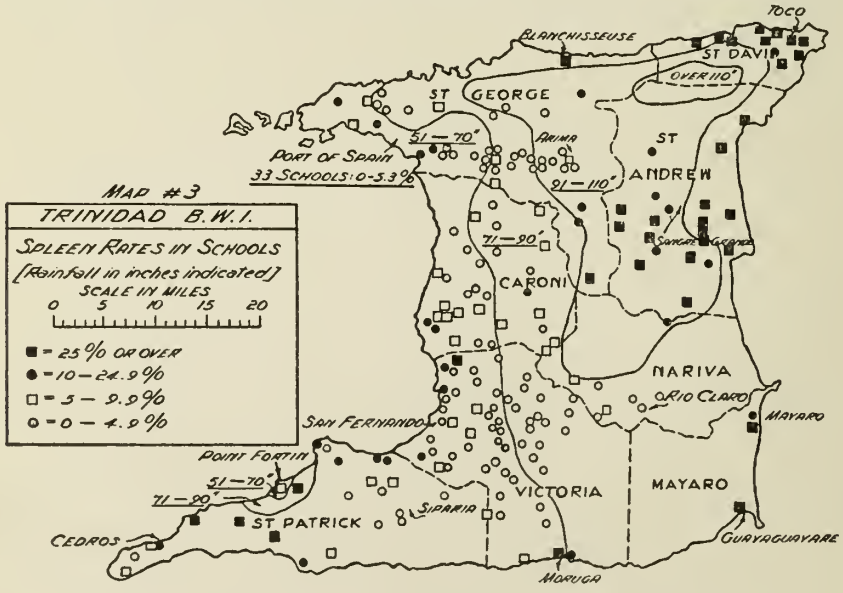
County (or City)	Number of Schools	Number of Children Present	Number of Children Examined	Number with Enlarged Spleens	Spleen Rate
St. David	10	745	546	290	53.1
St. Andrew	22	2,240	1,349	447	33.1
St. George (ex. Port of Spain)	51	10,883	4,612	277	6.0
Port of Spain	33	8,977	4,375	76	1.7
Caroni	34	5,659	2,741	176	6.4
Mayaro	3	350	200	75	37.5
Nariva	9	1,219	650	35	5.3
St. Patrick	27	5,227	2,719	241	8.9
Victoria (ex. San Fernando	56	8,556	5,324	180	3.4
San Fernando	8	3,055	1,425	26	1.8
Tobago	33	4,059	2,408	401	16.7
Total	286	50,970	26,349	2,224	8.4

TABLE XI.

Data from Blood Examinations of School Children—Trinidad and Tobago

County (or City)	SPLEEN NEGATIVE						SPLEEN POSITIVE					
	Smears Taken	Pos.	Viv.	Mal.	Fal.	Mix.	Smears Taken	Pos.	Viv.	Mal.	Fal.	Mix.
St. David	64	30	12	1	17	0	290	238	88	56	63	31
St. Andrew	233	46	12	6	28	0	446	213	51	28	129	5
St. George (ex. Port of Spain)	958	43	16	2	25	0	276	129	30	14	74	11
Port of Spain	1077	32	12	1	19	0	76	26	5	5	15	1
Caroni	581	42	21	0	21	0	175	53	32	2	17	2
Mayaro	48	16	2	1	12	1	75	48	7	11	24	6
Nariva	149	11	4	1	6	0	35	11	6	0	5	0
St. Patrick	713	58	16	3	36	3	240	134	24	13	89	8
Victoria (ex. San Fernando	1332	46	18	5	23	0	180	55	24	10	19	2
San Fernando	346	5	1	0	4	0	26	5	1	1	3	0
Tobago	830	146	13	21	107	5	399	253	22	65	154	12
Total	6,331	475	127	41	298	9	2,218	1,165	290	205	592	78

of the total number of children in the Colony, in the age group 5 to 15 inclusive. Two thousand two hundred and twenty-four children were found to have enlarged spleens, and blood smears were taken on 2,218 of them. Blood smears were also taken on a total of 6,331 children without splenic enlargement. Tables IX, X and XI give details of this investigation. The racial distribution is quite uneven, as shown in Table IX, some counties having predominantly negro, others predominantly East Indian populations. The highest spleen rates were found in St. David and St. Andrew Counties. The Sans Souci Roman Catholic School, in St. David's



County had a spleen index of 81.6%, the highest found in this survey.

Map No. 3 shows locations of schools and spleen rates in Trinidad and Map No. 10 shows locations of schools and spleen rates in Tobago.

In Table XII it is evident that the percentage of blood positives, both in the spleen positive and in the spleen negative groups, is highest in the regions where malaria is most prevalent, as shown by the spleen rates. This is much more striking if the schools are regrouped according to the spleen rates of each school, instead of by arbitrary county lines, as is shown in Table XIII and Graph. I.

TABLE XII.

Spleen Rates and Parasite Rates by County — Trinidad and Tobago

County (or City)	Spleen Rate	Spleen Negative Percent Parasite Positive	Spleen Positive Percent Parasite Positive
St. David	53.1	46.9	82.1
St. Andrew	33.1	19.7	47.7
St. George (ex. Port of Spain)	6.0	4.5	46.8
Port of Spain	1.7	3.0	34.2
Caroni	6.4	7.2	30.3
Mayaro	37.5	33.3	64.0
Nariva	5.3	7.3	31.4
St. Patrick	8.9	8.1	55.9
Victoria (ex. San Fernando)	3.4	3.5	30.6
San Fernando	1.8	1.4	19.2
Tobago	16.7	17.6	63.4
Total	8.5	7.5	52.5

TABLE XIII

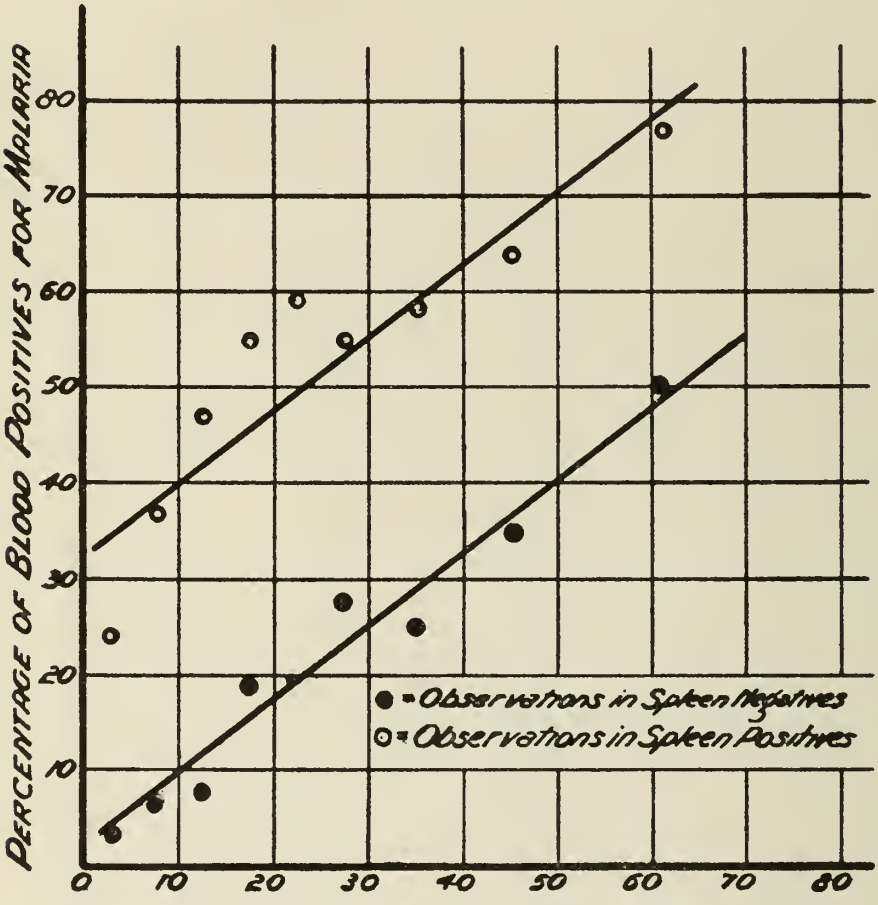
Parasite Rates Grouped According to Spleen Rates — Trinidad and Tobago

Spleen Rate of Schools	Number of Schools in Group	Spleen Negative Percent Parasite Positive	Spleen Positive Percent Parasite Positive
0 — 4.9	155	3.5	23.4
5 — 9.9	40	6.6	36.3
10 — 14.9	13	7.7	46.7
15 — 19.9	16	18.5	54.2
20 — 24.5	17	19.2	58.5
25 — 29.9	12	27.1	54.6
30 — 39.9	12	24.8	58.3
40 — 49.9	13	34.9	63.9
Over 50 (avg.60.9)	8	50.0	76.6

From Table XIV it can be seen that *P. falciparum* is by far the most common infection in the Colony. However, the other two species are by no means uncommon. In Tobago, as can be seen in Table XI, *P. falciparum* is the most common species encountered, with *P. malariae* second in importance.

GRAPH NO. 1

RELATIONSHIP OF SPLEEN RATE OF REGION TO BLOOD PARASITE RATE IN SPLEEN POSITIVE AND SPLEEN NEGATIVE CHILDREN.



SPLEEN RATE IN SCHOOL

TABLE XIV.

Proportions of Species of Malaria Parasites — Trinidad and Tobago

Species of Parasite	Number of Cases	Percentage of Total number of cases
P. vivax	413	26.7
P. malariae	242	15.6
P. falciparum	890	57.7
Total	1,545	100.0

Note: Double infections are not included.

P. malariae infections appear to be associated with splenomegaly more constantly than are the infections with the other two species of parasite, as Table XV shows.

TABLE XV.

Species of Malaria Parasite Grouped According to Degree of Splenomegaly

Spleen Size	Cases Positive for							
	Vivax		*Malariae*		*Falciparum*		Mixed	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0	127	30.8	39	16.1	298	33.5	11	12.2
P.D.I.	60	14.5	30	12.4	97	10.9	11	12.2
1	47	11.3	36	14.8	112	12.6	12	13.3
2	159	38.2	114	47.0	338	37.8	46	51.1
3	18	4.4	23	9.5	43	4.8	8	8.9
4	2	.5	0	.0	2	.2	2	2.2
Totals	413	99.7	242	99.8	890	99.8	90	99.9
Totals in Spleen Positive	286	69.2	203	83.9	592	66.5	79	87.8

However, this observation must be interpreted with some caution. In Table XI it appears that both *P. malariae* and mixed infections are relatively more common in the more malarious areas, where conditions are evidently very favorable for transmission of malaria. It is probable that most of the infected individuals in these areas would be found, if studied carefully enough, to harbor more than one species of parasite and, consequently, that too rigid interpretation of figures based on one blood examination alone may lead to error.

Table XVI gives the proportions of blood positives grouped according to spleen size. The decrease in the percentage of blood positives in the group with the largest spleens is interesting, and has been noted elsewhere by many other observers. There are too few included in the group "Spleen 4," however, to allow this observation to carry any statistical weight here. Schistosomiasis, a common cause of enlarged spleens in certain regions of Venezuela, has not been reported from Trinidad.

TABLE XVI.

Blood Positives Grouped According to Spleen Size — Trinidad and Tobago.

Spleen Size	Total Number	Positive	
		Number	Percent
0	6360	475	7.5
P.D.I.	623	198	31.8
1	518	207	40.0
2	951	657	69.1
3	108	92	85.2
4	12	6	50.0
Total	8572	1635	
Total in Spleen Positive	2212	1160	52.5

An analysis of the occurrence of the different species of parasite in the various racial groups is contained in Table XVII. The group designated as "other" in this table contains Europeans, Chinese and other races and admixtures not included in the three main groups. The numbers of the various elements composing this group are not large enough to make their individual analysis worth while. It appears from these data that *P. vivax* infections are relatively much more frequently found among the East Indians than among the Negroes and *P. falciparum* infections are relatively more frequent in the latter group. Only in the very malarious St. David County does the proportion of *P. vivax* infections exceed or even approach in frequency that of *P. falciparum* infections in the Negro group, whereas in most areas it does so in the East Indian group. *P. malariae* infections appear to occur relatively more frequently in Negroes; however, it is a common infection only in the very malarious counties of St. David, Mayaro and Tobago, in all of which the population is largely negro. Only if a large East Indian group could be subjected to similar experience could valid conclusions be drawn.

TABLE XVII.

Racial Distribution of the Species of Malaria Parasite.

County or City	Negro			Mixed			East Indian			Other		
	V.	M.	F.	V.	M.	F.	V.	M.	F.	V.	M.	F.
St. David	77	47	67	12	8	6	1	0	1	10	2	6
St. Andrews	16	19	74	10	7	24	33	6	51	3	2	6
St. George (ex. Port of Spain).	17	9	51	13	5	19	16	1	21	3	1	8
Port of Spain	7	6	21	5	0	7	3	1	2	2	0	4
Caroni	5	0	11	3	0	3	40	1	22	2	1	2
Mayaro	7	9	26	2	1	6	0	0	0	0	1	4
Nariva	0	1	1	1	0	2	9	0	4	0	0	4
St. Patrick	7	10	69	1	4	10	25	1	44	5	1	3
Victoria	4	6	17	6	3	8	31	5	24	2	0	0
Tobago	22	71	231	9	9	25	2	2	3	2	1	3
Total	162	179	568	62	37	110	160	17	172	29	9	40

Note: Double infections are not included.

Data on the relationship of spleen size to race are more difficult to analyze and interpret. Table XVII presents the data for the whole colony. From the totals for each racial group, in this table, it would appear that the Negro is more apt to respond to malarial infection with splenomegaly than is the East Indian. With more extended analysis it may be seen that this difference is more apparent than real. St. David County and Tobago, two of the most malarious areas, have populations largely composed of Negroes and the totals for Negroes are thus weighted by the contributions from these two areas. St. Andrew's County, very malarious, and with almost equal numbers of Negroes and East Indians deserves com-

TABLE XVIII.

Degree of Splenomegaly According to Race

Town or County	Spleen Size 0	P. D. I.	1	2	3	4	
		NEGRO					
St. David	207	49	37	115	15	2	
St. Andrew	378	49	30	65	7	2	
St. George	1,677	20	22	57	4	0	
Port of Spain	2,508	16	11	13	0	0	
Caroni	598	7	4	9	0	1	
Mayaro	89	17	17	19	1	0	
Nariva	149	2	2	0	0	0	
St. Patrick	854	27	33	37	2	0	
Victoria	2,296	19	11	5	0	1	
Tobago	1,762	60	80	193	6	0	
Total	10,518	275	247	513	35	6	11,594
		MIXED					
St. David	38	8	6	27	10	0	
St. Andrew	145	18	17	33	6	0	
St. George	873	17	16	36	3	0	
Port of Spain	995	8	4	1	0	0	
Caroni	174	6	5	6	0	0	
Mayaro	19	4	2	8	0	0	
Nariva	75	0	3	0	0	0	
St. Patrick	198	11	6	6	1	0	
Victoria	547	9	9	7	1	1	
Tobago	215	9	8	25	0	0	
Total	3,279	90	76	149	21	1	3,616
		EAST INDIAN					
St. David	3	0	1	1	0	1	
St. Andrew	317	46	22	105	23	1	
Port of Spain	421	6	5	3	0	0	
St. George	1,413	20	22	30	2	1	
Caroni	1,650	48	31	42	4	2	
Mayaro	11	0	1	0	0	0	
Nariva	368	15	8	1	0	0	
St. Patrick	1,298	27	36	31	7	0	
Victoria	3,329	53	47	26	2	0	
Tobago	12	1	0	4	1	0	
Total	8,822	216	173	243	39	5	9,498
		OTHER					
St. David	8	2	2	7	7	0	
St. Andrew	62	12	1	7	2	0	
St. George	356	4	7	14	1	0	
Port of Spain	375	6	2	0	0	0	
Caroni	144	4	2	3	1	0	
Mayaro	6	2	1	3	0	0	
Nariva	23	2	1	1	0	0	
St. Patrick	125	5	5	5	2	0	
Victoria	371	5	2	5	0	0	
Tobago	18	0	0	5	0	0	
Total	1,488	42	23	50	13	0	1,616
Grand Total	24,107	623	519	955	108	12	26,324

ment. Here it appears that the East Indian group has a higher proportion with enlarged spleens and a higher proportion of the larger spleen sizes. However, from the data at hand, we are not justified in reaching any definite conclusions about racial tendencies to develop splenomegaly as a response to malarial infection.

There is very little difference in the percentage with enlarged spleens in the age groups 5 - 9 and 10 - 14, as is shown on Table XIX.

TABLE XIX.

Relationship of Age to Splenomegaly

Age Group	Total Number	Number with Splenomegaly	Percent with Splenomegaly
5 - 9	14,856	1,307	8.1
10 - 14	11,397	891	7.8

In Tobago an interesting correlation was found to exist between spleen rates in schools and the altitude of the school. There are seven schools located at an altitude of 400 feet or more above sea level. The rates in these schools were much lower than the rates of schools located in more low lying regions. The differences in rates are actually more striking than Table XX indicates, since most of the children with enlarged spleens in the seven schools were found on careful questioning, to come from low lying areas several miles away. The higher lands of Tobago are usually at a considerable distance from favorable *A. aquasalis* breeding grounds. This is probably the explanation for the low incidence of malaria in such regions.

Similar observations are not possible for Trinidad, since, of the few schools located over 400 feet above sea level, most are in *A. bellator* territory and have high spleen rates.

TABLE XX.

Altitude	Number of Schools	Number Children	Number with Enlarged Spleens	Spleen Rate
0 - 199	21	1,558	309	19.8
200 - 399	5	350	75	21.4
400 and over	7	500	16	3.2
Total	33	2,408	412	

ANOPHELINE SURVEY

Investigations of anopheline breeding areas and captures of adult anophelines were carried out largely by Mr. Jurawan and Mr. Gilkes, Sanitary Inspectors of the Health Department. Other members of the staff have devoted much time also to field investigations and particularly to the anopheline vectors of malaria. Routine col-

lections were made from numerous localities in Trinidad and Tobago, material being brought into the laboratory for rearing and final identification.

The following discussion is focussed especially upon the relationship of anophelines to malaria in Trinidad and Tobago, and no attempt is made here to present detailed data on the biology of the various anopheline species. Mr. R. C. Shannon has been working on the details of the biology and taxonomy of the Trinidad anophelines and this material will be presented in a later publication. Mr. C. S. Pittendrigh has been working on the botanical and ecological problems pertaining to the bromeliad-breeding anophelines and the results will also be published later.

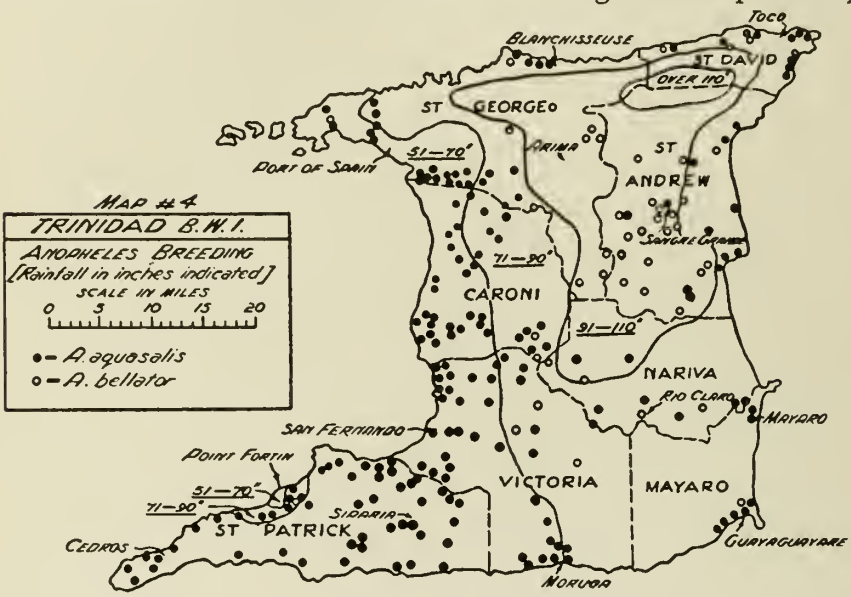
Thirteen species of anophelines have been found in Trinidad during this survey, and three in Tobago. Those not reported in earlier lists (5, 6, 7, 8, 16), have been marked with an asterisk. The report of *A. albimanus* (16) has since been considered to have been a misidentification. Other reports, such as *A. argyritarsis, A. maculipes, A. punctimacula* have never been confirmed. *A. pseudopunctipennis* has been reported many times in the past, and there can be no question but that it was once in Trinidad. We have failed to find it on this survey. Table XXI gives the number of larval and adult collections made of each species. These figures provide a rough index of the abundance of the species but considerably more attention has been paid to those species suspected

TABLE XXI.

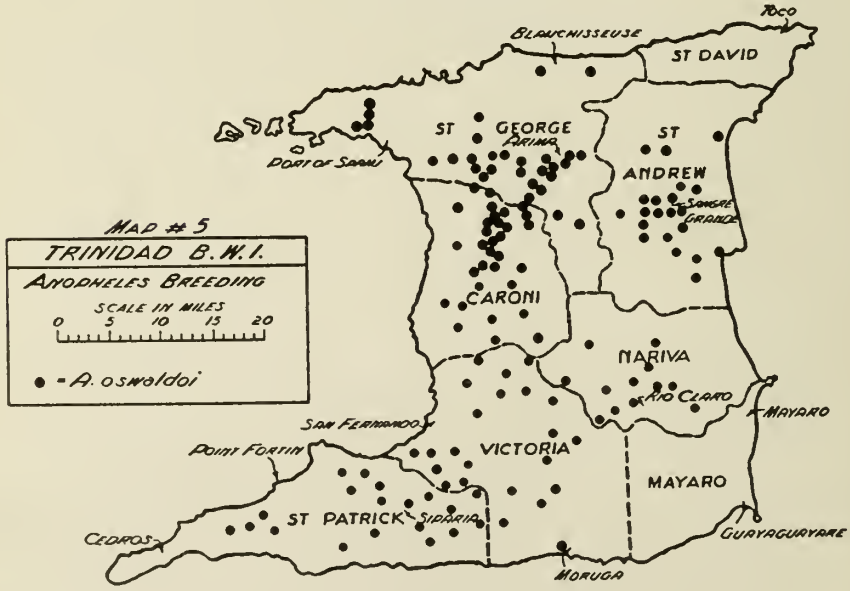
Collections of Anopheles Larvae and Adults
*species not reported previously

Species	Larval Collections	Adult Collections.
Trinidad		
A. aquasalis.	367	184
A. oswaldoi.	195	12
A. albitarsis	106	18
A. neomaculipalpus.	63	24
A. apicimacula.	7	7
A. mediopunctatus.	5	3
* *A. (Arribalzagaia) sp.*	4	2
A. nimbus.	2	2
A. eiseni.	4	1
A. bellator.	37	64
* *A. homunculus.*	10	9
* *A. anoplus.*	?	?
* *A. (Kerteszia) sp.*	?	?
Tobago		
A. aquasalis.	74	—
A. neomaculipalpus.	4	—
* *A. apicimacula.*	2	—

of being vectors. No attempt has been made to tabulate the numbers of individuals of the various species bred out in the laboratory or captured as adults. A total of 467 Trinidad larval collections were identified as to species and 243 adult captures were made. 77 of the larval collections made in Tobago were specifically

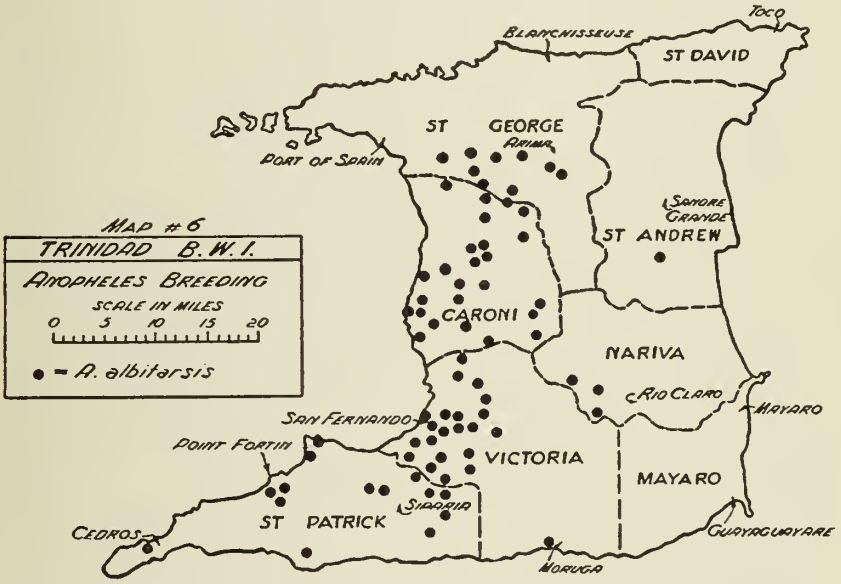


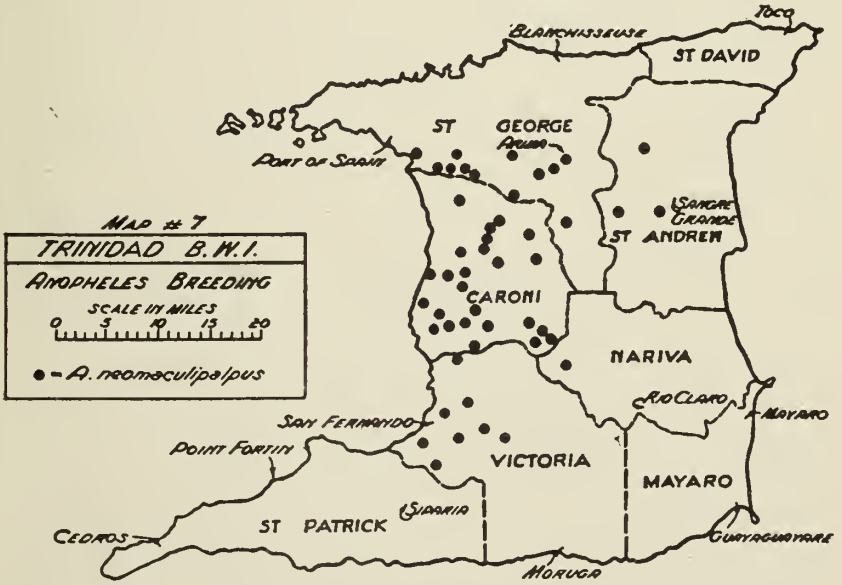
BREEDING OF IMPORTANT VECTORS OF MALARIA

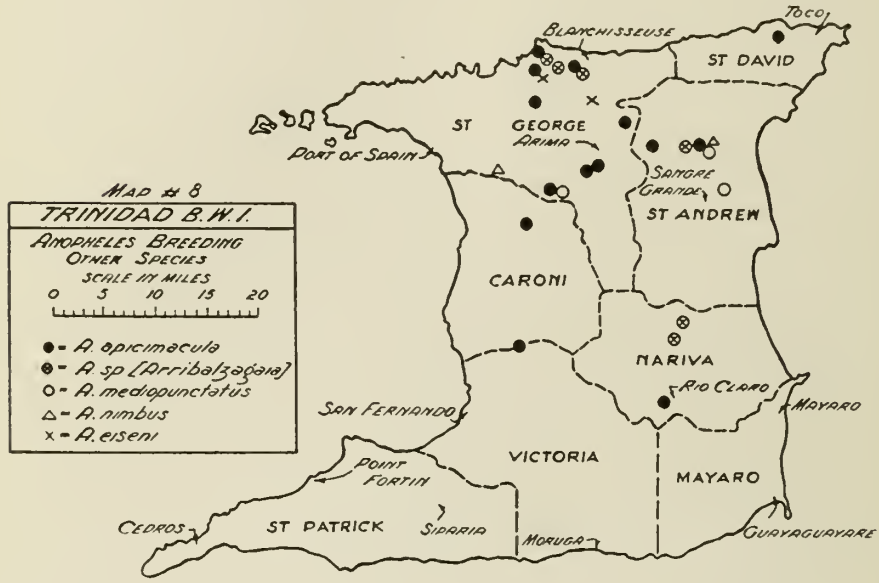


identified.

The distributions of the species in the Colony are shown on Maps 4, 5, 6, 7, 8 and 12.






MAP # 8
TRINIDAD B.W.I.
ANOPHELES BREEDING
OTHER SPECIES
SCALE IN MILES
0 5 10 15 20
● - A. apicimacula
⊗ - A. sp. [Arribalzagaia]
○ - A. mediopunctatus
△ - A. nimbus
× - A. eiseni
TOCO
BLANCHISSEUSE
ST DAVID
ST GEORGE
ARIMA
PORT OF SPAIN
SANGRE GRANDE
ST ANDREW
CARONI
MARIVA
RIO CLARO
MAYARO
SAN FERNANDO
VICTORIA
POINT FORTIN
MAYARO
CEDROS
ST PATRICK
SIPARIA
MORUGA
GUAYAGUAYARE


TOBAGO B.W.I.
ANOPHELINE BREEDING
SCALE IN MILES
0 5 10
● - A. aquasalis
● - A. apicimacula
○ - A. neomaculipalpus
MAP #12
CHARLOTTEVILLE
PARLATUVIER
SPEYSIDE
CASTARA
ROXBOROUGH
DELAFORD
PLYMOUTH
MORIAN
MASON HALL
MT. ST. GEORGE
GOODWOOD
LAMBEAU
SCARBOROUGH

A. aquasalis is the common coastal anopheline of both Trinidad and Tobago. It breeds freely in brackish water; along the fringes of the mangrove swamps, in ditches in coastal coconut plantations, in ditches in the sugar cane plantations and in the water penned up behind the sand bars which block the mouths of the small streams flowing into the ocean. They have also been found breeding above the limits of brackish water, in freshwater streams, as far as ten miles inland. Larvae are not uncommonly found in standing pools of water, fully exposed to the sun; in roadside borrow pits and in rice fields. Although, as mentioned above, the species has been found far inland, still, it is much more abundant in the coastal regions. The adults feed freely on animals and man and enter stables and houses readily. They usually leave such shelters before or at dawn and house captures yield only a small number of mosquitoes per house, unless they have been trapped by the closing of a window or by getting inside a bed net.

A. oswaldoi is a common anopheline in certain of the inland regions of the island. Breeding occurs in fresh water, usually in the grassy margins of streams and pools. Adults are rarely seen in great numbers. They have been observed feeding on man but can be collected most consistently in stables.

A. albitarsis is a common species of inland Trinidad, breeding in fresh water, in rice fields, grassy savanna pools and along the quiet margins of stream pools. In certain regions adults are common, and can be picked up in considerable numbers in stable collections. They feed freely on man in regions where they are abundant. House collections have yielded only very small numbers of this species, and its habits appear to coincide with those of *A. aquasalis,* in that it attempts to leave shelters shortly after feeding.

A. neomaculipalpus is a common species in inland Trinidad and is found also in Tobago. This species is found breeding in fresh water, in rice fields, savanna pools and open meadow pools and has been found even in the very turbid, foul water of pig wallows. Large numbers have been found in stables close to breeding areas. It is occasionally observed biting man and has been taken rarely in house captures.

A. apicimacula is an uncommon species both in Trinidad and Tobago. It is usually found breeding along the quiet margins of pools in clear hill streams. Adults have been observed only on a few occasions and in one instance were caught in numbers feeding on man.

A. mediopunctatus is rare. Breeding occurs in forest pools. Adults have rarely been observed.

A. (Arribalzagaia) sp. is rare except in certain localities. Breeding preferences are similar to those of *A. apicimacula* and this species has also been caught feeding on man.

A. nimbus is rare. Breeds in forest pools. Adults have been taken, biting during the daytime.

A. eiseni is uncommon. It has been found breeding along the margins of pools of clear hill streams.

A. bellator is abundant in the heavy rainfall zone of central and northern Trinidad. It reaches almost fantastic concentrations in the areas of cocoa cultivation where the immortelle trees are planted as windbreaks and shade for the cocoa trees. Certain of the larger bromeliads are particularly important as host plants of *A. bellator, (Gravisia aquilega, Wittmackia lingulata, Hohenbergia stellata, Vriesia amazonica)*. The immortelle trees provide ideal lodging sites for these plants. However, it is most important to note that, in areas of cocoa cultivation in southern, southwestern and northwestern Trinidad, where the immortelles and bromeliads are both abundant, *A. bellator* has been noted to be rare or absent. We feel that this can be correlated with lower rainfall of these areas (see Map No. 2). De Verteuil (15) and Rozeboom and Laird (17) have given detailed discussions of the habits of this species. The adults bite humans freely. In the Cumuto area as many as 950 anophelines have been collected from four small boys sitting by the roadside in the period of an hour and a half. The females come in greatest numbers in the dusk period of 6:30 and 7:00 p. m. and, as soon as it becomes completely dark, the numbers fall off greatly. Collections made in the early morning yield much fewer mosquitoes. Adults are frequently observed biting during the daytime, in the bush and on humid days may be taken in numbers. Simultaneous collections inside and outside of houses have yielded, on several occasions, only a tenth to a quarter as many mosquitoes inside as outside. Once having fed indoors, the adults attempt to get out almost immediately. Stable captures and captures from animals have yielded only small numbers of *A. bellator* even in regions where the mosquito is very abundant.

A. homunculus, A. anoplus and *A. (Kerteszia) sp.* are all much rarer bromeliad breeding anophelines than *A. bellator*. Their habits, insofar as we have observed them, are similar to those of *A. bellator*.

NATURAL INFECTIONS IN ANOPHELINES

Captured mosquitoes were brought into the laboratory and kept for a period of from three to four days in order to digest their blood meals, before being dissected. In some of the positives, with

small oocysts, it is probable that the infection was derived from the feeding on the day the mosquito was captured; but in at least half of the oocyst positive specimens the oocysts were of such size that it was obvious that they had developed from some previous feeding. Many of the positive stomachs have been stained with Mayer's acid haemalum but it has been found that more accurate counts of numbers of oocysts can be made on the fresh preparations in saline under cover glasses.

In dissections to date (Table XXII) only two species of anophelines have been found infected in nature, *A. aquasalis* and *A. bellator*. However, only small numbers of the other species have been dissected. Collections made from various parts of the island have yielded only *A. aquasalis* and *A. bellator* biting man in any numbers and it is difficult to collect large numbers of the other species, unless captures are made in stables. The collections of house caught *A. aquasalis* referred to in Table XXI were made largely in Success Village and Barataria, two towns just to the east of Port of Spain. 588 dissected between September 1, 1941 and June 30, 1942 yielded only 5 oocyst positives, while 862 dissected between June 30, 1942 and October 19, 1942 have yielded 41 oocyst positives. The stable caught *A. aquasalis* came largely from stables in St. Joseph and Curepe, in the same region of the island. The collections of *A. bellator* were made almost entirely from boys, standing out of doors. Most of the material came from the vicinity of the Cumuto Canadian Mission School, where Rozeboom and Laird (17) made collections earlier in 1941. Other collections were made at Sangre Grande and at Tamana. Although only 10 oocyst positives are recorded in all, it is interesting to note that three of these infections occurred in a group of 91 *A. bellator* caught on December 12, 1941 near Sangre Grande, and five infections in a group of 340 caught on September 25, 1942 near Cumuto C. M. School.

The collections of *A. albitarsis* were made from houses at St. Helena Village near Piarco Airport. *A. albitarsis* is abundant here, and breeds in the innumerable small pools found in the nearby savanna. *A. neomaculipalpus* is also common in this region but rarely enters houses; *A. aquasalis* is uncommon. The spleen rate of children in the school at St. Helena is 9.3 per cent.

The collections of *A. oswaldoi* came largely from a stable near Cumuto; of *A. neomaculipalpus* from stables at Curepe.

Of the 46 oocyst positive *A. aquasalis*, 40 of the infections were caused by *P. falciparum*. Six of these were recorded as "positive" (no oocyst count made), 16 had from one to ten oocysts, ten had from ten to 20 oocysts, four had from 20 to 30 oocysts,

two had from 30 to 40 oocysts, one had 48 oocysts. Four of the infections were caused by *P. vivax*, with five, five, nine and eleven oocysts respectively. Two infections were mixed *P. falciparum - P. vivax*. Only one sporozoite infection was encountered, in a specimen from Success Village. There were no oocysts on the stomach.

Two of the ten oocyst infections of *A. bellator* were caused by *P. falciparum* with four and 30 oocysts respectively. One infection was recorded as "positive" (no oocyst count made). Seven infections were caused by *P. vivax* with one, five, ten, 25, 28, 30 and 51 oocysts respectively.

In recording species of parasite-producing oocysts, it should be recalled that in all cases such identifications cannot be absolute.

TABLE XXII.

Results of Dissections of "Wild Caught" Anophelines

Species	Where Caught	Total Number Dissected	Stomachs			Salivary Glands	
			Total Dissected	Number Positive	Percent Positive	Total Dissected	Number Positive
aquasalis	House	1450	1383	46	3.3	1364	1
	Stable	386	368	0	0	350	0
bellator	Outdoors	1426	1263	10	0.78	1348	0
albitarsis	House	19	16	0	0	18	0
oswaldoi	Stable	21	21	0	0	21	0
neomaculipalpus.	Stable	46	46	0	0	45	0
homunculus	Outdoors	5	5	0	0	5	0
apicimacula	Outdoors	3	3	0	0	3	0
Total		3356					

EXPERIMENTAL INFECTIONS IN ANOPHELINES

Malaria therapy for the treatment of general paresis was instituted in St. Ann's Mental Hospital. Nine negro patients were treated with *P. falciparum* and one white patient with *P. vivax*. It was possible to conduct a series of feedings of anophelines on these patients, controlling the observations by making a gametocyte count, using Earle's technique, before each feeding, and, when possible, feeding two or more species of anophelines at the same time, in order to make more satisfactory comparisons of the susceptibility of the various species. The adults of *A. aquasalis, A. bellator, A. albitarsis, A. neomaculipalpus* and *A. oswaldoi* used in these feedings were all reared from eggs obtained from wild caught females.

In most instances, material was held only for a period of from six to nine days and dissected to observe the incidence of oocysts. In a few instances material was held for a longer period to observe sporozoite infections.

In Table XXIII are presented the results of a series of feedings on patients with *P. falciparum* infections. In all cases the gametocyte level was in excess of 50 per cubic millimeter of blood and gametocytes had been observed in the blood for a period of at least five days before the experimental feedings were attempted. Even so, some feedings with high gametocyte levels gave very poor infection rates and some patients were also evidently "poor infecters" even when their gametocyte counts were high. Space does not permit a detailed analysis of these feedings here.

TABLE XXIII.

Experimental Infections of Trinidad Anophelines — *P. falciparum*

Species	Number of Feedings	Number of Mosquitoes Dissected	Total No. Stomach Positive	Percent	No. Dissected after 11 days	No. Stomach Positive	No. Salivary Gland Positive
aquasalis	31	408	167	40.9	21	14	9
bellator	6	52	27	51.9	13	6	3
albitarsis	15	157	37	23.5	46	2	1
neomaculipalpus	6	18	1	5.5	0	0	0
oswaldoi	3	15	1	6.7	0	0	0

The above table expresses total percentages, and is misleading. Actually, when results are compared on feedings in which two or more of the three species, *A. aquasalis, A. bellator* and *A. albitarsis,* were fed at the same time, infection rates are so closely comparable that it is doubtful that any difference in susceptibility exists. The low rates for *A. albitarsis* are largely explained by the fact that large numbers of them were fed on several occasions along with small numbers of *A. aquasalis,* on "poor infecters." The rates for *albitarsis* were seriously affected, the rates for *aquasalis less* markedly so. Similarly, the feedings with *bellator* were all good feedings and *aquasalis* fed at the same time showed similar infection rates. The numbers of *neomaculipalpus* and *oswaldoi* are so small that attempts at interpretation will not be made. Small numbers of *A. apicimacula, A. nimbus* and *A. homunculus* were fed, and failed to become infected (even though the gametocyte count was high) but at a time when a group of *A. aquasalis* and *A. albitarsis* also fed had such low rates that the failure of the other species to become infected cannot be taken to imply a low degree of susceptibility.

Experimental transmission of *P. falciparum* infections was successfully carried out both with *A. aquasalis* and *A. bellator.* In each instance, the patients at the St. Ann's Mental Hospital had been in residence at the hospital for at least a year. It was not possible to determine past malaria histories in these patients but

their records while in the hospital contained no reference to malaria during their residence there. Examination of the blood of each patient, by the thick drop technique, prior to infection, revealed no malaria parasites. The first patient, a negro, was infected by the bite of two *A. aquasalis*. These mosquitoes had been fed on a gametocyte carrier 13 days previously. They were then applied to the patient in the hospital and were both observed to feed. Dissection of both mosquitoes after feeding revealed large numbers of sporozoites in the salivary glands. The patient's blood was examined daily, beginning the seventh day after infection and parasites were first observed on the thirteenth day. The patient developed a severe *P. falciparum infection.* The second patient, also a negro, was infected by the bite of one *A. bellator.* This *mosquito* had been fed on a gametocyte carrier 15 days previously. After feeding on the patient, it was dissected and found to be sporozoite positive. Parasites were first observed in the blood of the patient on the twelfth day after infection. This patient developed a rather mild *P. falciparum* infection.

Six feedings have been carried out on a patient with *P. vivax* malaria. Gametocyte counts have ranged from 60 to 550 per cubic millimeter and the observations cover a period of thirty days. However, very poor infection rates have been obtained and the infections have been very light, with from one to five oocysts per stomach.

TABLE XXIV.

Experimental Infections of Trinidad Anophelines – *P. vivax*

Species	Number of Feedings	Number of Mosquitoes Dissected	Total Number Stomach Positive	Percent
aquasalis	6	90	8	8.9
bellator	1	4	0	0
neomaculipalpus	2	2	0	0

In the feeding in which the *A. bellator* failed to become infected five *A. aquasalis* fed were also negative.

One specimen of *A. aquasalis* had sporozoites in the salivary glands after a period of nine days.

It was noted during the course of the experimental feedings that *A. aquasalis* feeds readily when placed on a patient, at any hour of the day, and that *A. bellator* and *A. albitarsis* feed somewhat less readily. Both *A. neomaculipalpus* and *A. oswaldoi* were always most reluctant to feed.

DISCUSSION

From data assembled from spleen surveys and observations of anopheline breeding and adult habits and densities in various parts of the island, it is possible to formulate a general plan of the malaria problems of Trinidad and Tobago. Indeed, this formulation does not differ fundamentally from ideas previously expressed by De Verteuil (12), (15).

By referring to Maps Nos. 3 and 10 showing the spleen rate in schools, it can be seen that those schools located near the coast line in Trinidad and Tobago almost invariably have high spleen rates. The one common factor for all of these localities is the presence of *A. aquasalis* (see Map No. 4). Most of the small coastal towns in Tobago and the coastal towns on Trinidad's north, east and south coasts are located where a small stream, or several small streams enter the ocean. These stream mouths usually remain open during the wet season, when the heavy rains periodically flush out the streams and cause them to break through the sand bars. However, during the dry season, the stream mouths become blocked by sand bars and the waters are dammed up behind the barriers. In some instances only a small pool is thus formed but in many cases several acres of ground may be flooded. The water remains dammed up until it gets sufficient head to break through the sand bar, which it may do once or twice during the dry season. Conditions are ideal for the breeding of *A. aquasalis* in this type of locality.

Some of the larger, permanent coastal swamps, such as Caroni, Laventille, Nariva, Cocorite and Rousillac, support more or less heavy breeding throughout the year. During the driest part of the dry season, however, densities of larvae and adults may be greatly reduced. It is interesting to note that in certain localities near the Caroni Swamp, where production of *A. aquasalis* is very great for most of the year, the spleen rates are considerably lower than in the isolated coastal communities where *A. aquasalis*, although present, exists in much smaller numbers. It is possible that the presence of many animals, water buffalo, oxen, donkeys and cows in the former region may act as barriers to divert large numbers of the mosquitoes from feeding on humans. Many of the isolated coastal villages have little or no livestock; man must, therefore, serve as the main source of blood for the mosquitoes.

Permanent control measures for *A. aquasalis* breeding fall naturally into two categories; namely, extensive and expensive swamp reclamation programs for the large swamps of the island and small, but carefully planned projects to provide free outlet to the sea for the numerous small coastal streams. Secondary measures of im-

portance include the straightening and clearing of the streams for a distance of a mile or more upstream from the mouth and careful planning and cleaning of drains on coconut and sugar plantations in the coastal areas. In some areas tidal flushing of the ditches in coconut plantations can be used to advantage.

Temporary measures include oiling and application of Paris green. These measures should be very successful in certain coastal regions where the actual breeding territory of *A. aquasalis* may be very limited and where breeding occurs mainly in the dry season.

In most areas of inland Trinidad, away from the coast, breeding of *A. aquasalis* is rare or even absent. In many such areas, i. e. around Arima, and east of San Fernando, malaria rates are low, even though other anophelines, such as *A. albitarsis, A. neomaculipalpus* and *A. oswaldoi* are common in the region. It can be safely said that malaria does not constitute a serious health hazard in these regions, and that it would be unwise to direct efforts against the ground breeding anophelines of these regions, at least until other far more malarious areas have been handled satisfactorily. It is doubtful if any of the above three species serves as an efficient vector of malaria in Trinidad.

However, referring again to Map No. 3 we see one island area of Trinidad, namely, central and northcentral Trinidad, where high spleen rates are found. If Map No. 4 be consulted, it can be seen that this area coincides almost exactly with the breeding range of *A. bellator*. It also is evident that the breeding range of *A. bellator* coincides very well with the zones of highest rainfall for the island, Map No. 2. It cannot be shown on a map of this type, but field collections both of larvae and adults have demonstrated, time and again, that the actual densities of the mosquitoes drops off greatly, as one passes south and east out of the zone of heaviest rainfall, and it has also been noted that the spleen rates in the schools fall off markedly in passing out of the zone of heaviest rainfall, and the zone of greatest densities of *A. bellator*. The schools with the lowest spleen rates in Trinidad were found in south central Trinidad between the *A. bellator* zone and the coastal *A. aquasalis* zone.

The relationship of the other three bromeliad anophelines of Trinidad, *A. homunculus, A. anoplus* and *A. (Kerteszia) sp.* to malaria requires further investigation.

Malaria transmitted and maintained at a high level of endemicity by *A. bellator* is unique and most important to Trinidad. The obvious control methods are to cut down either the Bromeliad plants alone or the immortelle trees on which they chiefly grow. Neither is practical from an economic standpoint. The small agriculturist,

living in the midst of a forest of immortelle trees on a cocoa plantation on which his very existence depends cannot afford to dispense with his livelihood in order to avoid malaria. A cheap, practical method of control has yet to be found.

SUMMARY AND CONCLUSIONS

1. Examination of 26,349 school children between the ages of five and 15 in Trinidad and Tobago or roughly one quarter of the total number of children in the Colony revealed a spleen index of 8.4%. The counties of St. David, St. Andrew and Mavaro, the northwestern portion of St. George (near Port of Spain), the southwestern portion of St. Patrick, and the island ward of Tobago were the most malarious areas.

2. Examination of 8,549 blood smears indicated *P. falciparum* to be the most common infection, *P. vivax* next and *P. malariae* the least common. However, in some of the more malarious regions, *P. malariae* equalled or exceeded *P. vivax* in frequency.

3. There does not appear to be any marked difference between the negro and the East Indian children in the occurrence of splenomegaly. However, it does appear that *P. falciparum* infections are relatively more frequent in the negro children and *P. vivax* infections relatively more frequent in the East Indians.

4. Of the 13 species of Anopheles found in Trinidad, only five occur in numbers sufficient to direct attention to them as possible important vectors of malaria, namely: *A. aquasalis, A. oswaldoi, A. albitaris, A. neomaculipalpus* and *A. bellator*. The first four breed in ground waters, whereas *A. bellator* breeds in bromeliads, the waterholding plants growing on trees.

5. Dissections of "wild caught" anophelines reveal 46 or 3.3% oocyst positives in 1,364 house caught *A. aquasalis*. Only one salivary gland positive has been found. Ten or 0.78% oocyst positives were encountered in 1,263 dissections of *A. bellator* captured out of doors. No salivary gland positives have been observed. Small numbers of house caught *A. albitarsis* and stable caught *A. oswaldoi* and *A. neomaculipalpus* were free of parasites. However, the numbers are so small that it is not justifiable to form definite conclusions from this evidence alone.

6. In experimental feedings, *A. aquasalis, A. bellator* and *A. albitaris* have all been found to be very susceptible to infection with *P. falciparum*. Insufficient work has been done with *A. oswaldoi* and with *A. neomaculipalpus* to arrive at definite conclusions regarding their susceptibility. Also insufficient work has been done with experimental infections with *P. vivax* to warrant drawing any

conclusions.

7. *P. falciparum* malaria has been transmitted in one instance by the bite of two experimentally infected *A. aquasalis* and in another instance by the bite of one similarly infected *A. bellator.*

8. Reference to the maps of anopheline distribution and to the map of spleen rates in schools shows the close correlation between the presence of malaria and presence of one or both of the species, *A. aquasalis* and *A. bellator.* Further analysis of the *A. bellator* region in central Trinidad reveals close correlation between densities of adult *bellator,* spleen rates, and rainfall. In areas of Trinidad where both the above species are rare or absent, malaria rates are very low.

9. *A. aquasalis* is the only malaria vector among the three species occurring in Tobago.

10. The survey discloses that about half of Trinidad is malaria free. The remaining portions, very irregular in size and distribution, may be classified as *bellator*-malaria-areas and *aquasalis*-malaria-areas. In a few areas both species operate. As shown by the biology of the two species, malaria control in Trinidad, in order to be effective and economical, must be directed specifically toward either *bellator* or *aquasalis,* occasionally both.

Very contrary methods are necessary for each of these species. It is useless to attempt draining and oiling ground waters when the culprits are breeding overhead in bromeliads growing on tree branches and needless to give attention to bromeliads when *aquasalis* is the only vector present. Furthermore in certain areas of Trinidad where *A. bellator* and *A. aquasalis* are both rare or absent, and malaria is also uncommon, measures for control of other ground breeding anophelines probably have little value except as pest control procedures.

In Tobago *A. aquasalis* is the only vector of any importance.

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Doctor P. J. Crawford, Director of the International Health Division's activities in the Caribbean Region, arranged for this survey at the invitation of the Medical Services of the Colony. We are deeply indebted to him for his valuable guidance throughout the course of the project. Doctor Mark F. Boyd of The Rockefeller Foundation, International Health Division, planned the organization, and participated in operation of this survey, remaining in Trinidad for a period of three months. Professor A. M. Goodman of Cornell University, devoted two months to a surveillance of the drainage problems of the island. Mr. Colin S. Pittendrigh, student at the Imperial College of Tropical Agriculture, has devoted much time and effort to the bromeliad problem during the past year.

Special mention is made of the devoted efforts of the members of the staff, which alone made possible the survey: Mr. Jurawan, Chief Sanitary Inspector; Mr. Gilkes, Sanitary Inspector; Miss Farfan and Miss Dasent, Technicians; Mr. Gonzales, Field Helper, and Mrs. Atkinson, Clerk.

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